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A Thesis

Submitted to the Faculty

of

Purdue University

by

Eugene Taylor Kirk

In Partial Fulfillment of the

Requirements for the Degree

of

Master of Science in Industrial Engineering

June, 1958

A CHECK LIST FOR THE THERBLIG HOLD

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ACKNOWLEDGMENTS

The author is deeply indebted to Professor H. T. Amrine under whose supervision this study was undertaken and whose guidance and help have been of inestimable value.

To Professors M. E. Mundel, W. J. Richardson and O. Musgrave, the author is grateful for their helpful suggestions.

To the staff and personnel of The Duncan Electric Company, Lafayette, Indiana, The Steven A. Young Company, Flora, Indiana, and the Naval Ordnance Plant, Indianapolis, Indiana, the author is obligated for the courtesies and assistance extended to him.

Finally to my wife, for her patience and understanding help, I shall ever be grateful.

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ABSTRACT

Often in industrial situations the non-productive therblig HOLD occurs and usually can profitably be eliminated by resorting to the use of some device to maintain the workpiece in a fixed position and location. This is especially true in hand operations such as assembly work and operations capable of being made bi-manual, where the versatility of the hand can be used to do more productive work.

The purpose of this study is to attempt to develop a check list which will facilitate a systematic approach to the problem of selecting or designing devices to eliminate the therblig HOLD.

A survey of texts on tool design and motion and time study as well as periodicals established basic principles that apply to fixtures which hold a workpiece while an operation is being performed. Using these as a guide a check list has been developed to apply to the therblig HOLD when it occurs. The list is arranged in a sequence so as to facilitate a logical approach to the problem of dealing with the situation and should provoke thought in such a fashion as to lead to the selection of a more suitable device to eliminate HOLD.

INTRODUCTION

In industry and other fields today the acceptance and application of Motion and Time Study is becoming more widespread. While Motion and Time Study is not a cure-all for existing faults it is a useful tool of efficient management.

When Motion and Time Study is applied, a logical procedure should be followed. Such a procedure in the case of its application for methods improvement should include (1) making a record of the work method, present or proposed, (2) analyzing the method and (3) working out an improved method.

One systematic means of recording the work method is by the use of therbligs. After the method is recorded the individual therbligs may be questioned as by the list of basic rules[1] below:

1. Try to have both hands doing the same thing at the same time or balance the work of the two hands.
2. Try to avoid the use of the hands for holding.
3. Relieve the hands of work whenever possible.
4. Eliminate as many therbligs or as much of a therblig as possible.
5. Arrange the therbligs in the most convenient order.
6. Combine therbligs when possible.
7. Standardize method and train worker.

Often in an analysis the therblig HOLD will appear. "Hold refers to the retention of an object after it has been

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1. Mundel, M.E., Systematic Motion and Time Study; New York, Prentice-Hall, Inc., 1947, pg. 127

grasped, no movement of the object taking place."[2] "HOLD begins when movement of part or object, which hand or body member has under control, ceases, consists of holding an object in a fixed position and location and ends with any movement."[3] By movement is meant deliberate and intentional changing of position or location. From its definition HOLD may be detected even without resorting to a formal and detailed method breakdown.

Under most circumstances HOLD is undesirable since the hand is a poor and nonproductive holding device. If, as is often the case, one hand merely holds the workpiece in position while the other performs the useful work, a large percentage[4] of the productive potential of the worker is lost. Also, holding is tiresome to the worker. By the use of a suitable holding device it is often possible to balance the hand patterns of the worker leading to higher production and an improved method.

Under unusual conditions, such as extremely short duration of the therblig, where the time of loading and unloading a holding device overbalances the time of HOLD it may be more economical to retain this therblig than to eliminate it.

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2. Barnes, R.M., Motion and Time Study; New York, John Wiley & Sons, Inc., 1949, pg. 98
3. Mundel, M.E., Ibid, pg. 104
4. 41%, Ischinger, E.Jr., An Analysis of Some Differences Between One and Two Handed Work, Thesis, Purdue University, June, 1950

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Usually it appears because it is the "natural thing to do" or the worker performing the job does not take a sufficiently detached view to question its existence.

In resorting to the use of some device to eliminate HOLD the cost of design, material and labor must be considered and must be offset by the saving made possible by the use of the device. Often it is possible to make a simple, inexpensive device for a short run job and by so doing reap the benefits of a better method.

In such reference works as Modern Shop Practice[5] may be found examples of jigs and fixtures for performing certain specific machining work which are of use in the design of new tools for comparable jobs. In addition the numerous texts on tool design discuss the principles of fixture design.

Based on the above it is felt that it would be beneficial to develop a systematic method of approach to the matter of analyzing the occurrence of the therblig HOLD. Often much time is consumed in "dreaming-up" devices that could be saved by a systematic approach.

---

5. Modern Shop Practice, American Technical Society; Chicago, 1940, Vol. 4

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3. Modern Shop Practice, American Technical Society, Chicago, 1940, Vol. 4

PURPOSE

The purpose of this study is to attempt to develop a check list which will facilitate a systematic approach to the problem of selecting or designing devices to eliminate the therblig HOLD.

APPROACH TO THE PROBLEM

To establish a clearer concept of the limits of HOLD the following amplification is undertaken. In the field of materials handling, pallets and skids are considered holding devices. Often such devices as pliers and wrenches "hold" workpieces but should usually be properly classified as tools being "used". Other devices for holding are known as jigs but these are usually associated with precision or machining work in which the hand could seldom properly hold the workpiece. Fixtures, which may be defined as "devices for holding work while an operation is being performed"[6], are distinguished from jigs by the fact that they do not guide the tool performing the operation. The name implies further that the device is "fixed" in location, but this is not always the case. The field of assembly offers an excellent opportunity for the elimination of HOLD by the use of fixtures.

In collecting material for this thesis a survey was made of tool design texts, motion and time study texts, and periodicals dealing with or devoting space to both tool design and methods improvement. The purpose of the survey was to obtain general information on fixture design and on such design as would apply to methods improvement. Most of the tool design

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6. Owen, H.F., Introduction to Tool Engineering; New York, Prentice Hall, Inc., 1948, pg. 111

texts consulted devoted some space to the principles of jig and fixture design. Also, in periodicals were found articles dealing with these principles, but there was not much information on the application of fixtures for methods improvement. The subject seemed worthy of further development.

From the tool design sources mentioned above, the common requirements of successful fixtures that were noted and felt to apply to methods improvement are:

(1). Positive holding.
(2). Simple construction, with few parts to move and wear and with parts attached so as to prevent their being misplaced.
(3). Simple operation, holding accomplished rapidly and foolproof in that workpiece will fit in only one way.
(4). Safety, as by avoiding sharp corners and giving the hands a free path for operation.
(5). Provide the operator a clear view of workpiece.

To these may be added such physiological principles as:

(1). Using stronger muscle groups, such as legs, with foot-operated vises.[7]
(2). The action of pushing is less fatiguing than the action of pulling.[8]
(3). Pressure by the hand is less fatiguing than the action of pressing the fingers and thumb together.[9]
(4). Balancing hand patterns.
(5). Making parts readily accessible.
(6). Sliding of components to assembly is easier and faster than picking up and transporting.

The endeavor of this paper is to use the principles stated above as a guide to develop a check list which will

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7. Mundel, M.E., Ibid, pg. 53

8. Holmes, W.G., Applied Time and Motion Study; New York, Roland Press Co., 1945, pg. 252

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provoke thought on the part of the methods analyst in what is felt to be a logical sequence when approaching the problem of considering the therblig HOLD, especially when the purpose of such analysis is to eliminate it by means of the adoption of a fixture to perform the function currently being accomplished by hand. Further, some features are suggested for inclusion in the fixture and some illustrative examples of fixtures and their application are included. It is felt the field of application of this study will include primarily hand operations such as assemblies dealing with smaller, lighter workpieces, operations adapted to rapid hand movement and operations capable of being made bimanual. This study is not an attempt to eliminate the tool engineer and his function. After a perusal of the tool engineering texts it is felt the tool engineer dealing with fixture design concerns himself with holding workpieces for machining operations, while the methods analyst or motion and time study worker deals with the broader picture of industrial performance including simpler hand operations as exemplified by assembly work. It would be extremely difficult to draw a hard and fast line of demarkation between the two fields. Perhaps this is well illustrated by an idea expressed recently. "No reputable engineer would attempt to design a machine without strict observance of scientific facts, yet too often designs are completed in disregard for the physiological and psychological facts that govern the operator's

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behavior."[10] This is further supported by the requirement of several large manufacturing companies that their tool engineers take an in-plant course in motion and time study and its application. Possibly the results of this study will be of use to workers in both fields of endeavor but it is thought those persons charged with methods analysis will be more likely to benefit from it.

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10. Carmichael, Colin, "Editorial", Machine Design, March, 1950

PREPARATION OF CHECK LIST

The survey of texts and periodicals established principles but left the troublesome question of how to apply them. Reflection on this question led to the establishment of a check list which lists, in sequence, the factors related to the operation and workpiece which govern the need for the method of holding and which, if considered carefully, should lead to a clearer and more effective choice or design of a device to replace the hand. It is felt such a list will focus attention on these factors and thereby contribute to a better selection. For the sake of clarity examples are given to amplify as deemed necessary.

It may be well to consider some of the limitations of the application of HOLD. Of necessity the piece must be such that it can be moved and usually supported by a hand during the performance of work. Further, it is not worthwhile to prevent movement by means of the hand alone if much force acts on the piece. Also, if the piece or pieces in turn must be held rigidly in place the hand can not be used as effectively as a pneumatic cylinder or a foot operated vise.

Using the principles previously stated, the following check list was made for the consideration of HOLD:

I. Resort to use of a device to eliminate HOLD.

   A. Will the use of a holding device permit balanced hand motions?

   B. Can dual fixture be used so both hands can do same things simultaneously?

   C. Can holding device be foot operated?

   D. Is it economical to resort to device?

   E. Does duration of HOLD warrant elimination?

   F. Does length of production run warrant the cost of making a device?

   G. Can a device already made be adapted?

   H. Can a device be made to serve this job and similar ones in the future?

II. Purpose of holding.

   A. Is axial movement prevented?

   B. Is lateral movement prevented?

   C. Is rotational movement prevented?

   D. Is a combination of these movements prevented?

III. Best position to hold the piece.

   A. Can piece be positioned so its weight helps hold it?

   B. What work areas must be made accessible to the worker's hands and view?

   C. Can all work areas be made accessible with piece in fixed position?

   D. If not, can they be properly presented by indexing the piece and/or fixture?

III. Best position to hold the piece. (cont.)

E. Can holding device be operated at the optimum angle of inclination?

IV. Selection of piece or part of piece to hold.

A. Has piece a regular geometrical cross section?

B. Is cross section for example:

1. Circular?
2. Eliptical?
3. Triangular?
4. Rectangular?
5. Octagonal?

C. Can advantage be taken of cross section to adapt a wrench or similar device to do the holding?

D. If shape is irregular, can a regular cross section be used advantageously and still support required areas?

E. Can projections or other irregularities be used to help HOLD?

F. Are projections strong enough to hold piece?

G. Which parts of piece must be bridged?

H. Can piece or pieces held be slid to assembly?

III. Best position to hold the piece. (cont.)

C. Can holding device be operated at the optimum angle of inclination?

IV. Selection of piece or part of piece to hold.

A. Has piece a regular geometrical cross section?

B. Is cross section for example:

1. Circular?
2. Elliptical?
3. Triangular?
4. Rectangular?
5. Hexagonal?

C. Can advantage be taken of cross section to adapt a wrench or similar device to do the holding?

D. If shape is irregular, can a regular cross section be used advantageously and still support required stress?

E. Can projections or other irregularities be used to help hold?

F. Are projections strong enough to hold piece?

G. Which parts of piece must be bridged?

H. Can piece or pieces held be slid to assembly?

V. Nature of the material in the workpiece.

A. Is it hard? (Surface difficult to penetrate)

B. Is it soft? (Surface easy to penetrate)

C. Is it brittle? (Not capable of withstanding much pressure on surface)

D. Is it flexible? (Yields readily without permanent deformation)

E. Is it fragile? (Easily broken)

F. Is it a combination of above?

VI. Preservation of surface finish.

A. May surface be marred?

B. May surface be marred slightly?

C. Must surface finish be preserved?

D. How difficult is it to mar surface?

VII. Disposal of piece after completion of operation.

A. Can drop disposal be used?

B. Can fixture be used for succeeding operations(s)?

C. Does piece need to be positioned in another fixture?

DISCUSSION OF CHECK LIST

Probably the first consideration in analyzing the occurrence of the therblig HOLD is to determine whether or not it is advisable to eliminate it. Ultra short hand holding should not be eliminated since the time of loading and unloading the device would probably overbalance the time of holding and the cost of the device would not be returned. If, after the above consideration, it is deemed advisable to resort to a holding device a logical procedure should be followed in designing the fixture although each workpiece will be an individual case. Such a procedure should include, generally in the order named, consideration of the following steps:

1. Resort to use of a device to eliminate HOLD.

   If the operation is such that both hands can perform useful work and in a balanced pattern, resort to a fixture is advisable. Further, if possible, both hands should do the same thing simultaneously. The hands can often be freed for productive work by the use of foot operated devices such as shown in Figure 1 and Figure 2.

ELIMINATION OF HOLD TIME

Probably the first consideration in analyzing the occurrence of the therblig HOLD is to determine whether or not it is advisable to eliminate it. Since short hand holding should not be eliminated since the time of loading and unloading the device would probably overbalance the time of holding and the cost of the device would not be returned. If, after the above consideration, it is deemed advisable to resort to a holding device a logical procedure should be followed in designing the fixture although each workpiece will be an individual case. Such a procedure should include, generally in the order named, consideration of the following steps:

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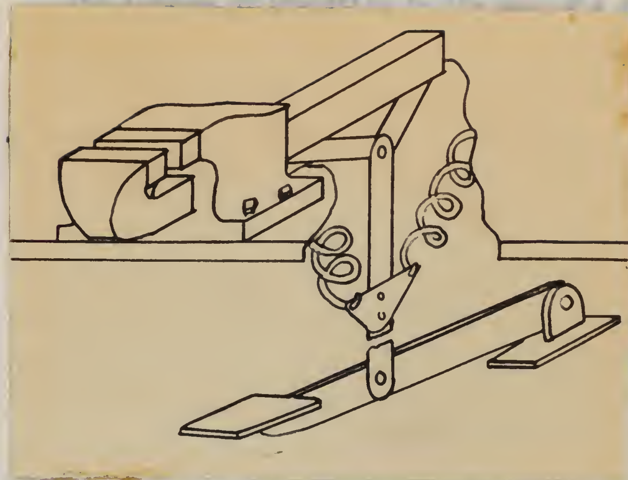

Fig. 1 Foot Operated Vise

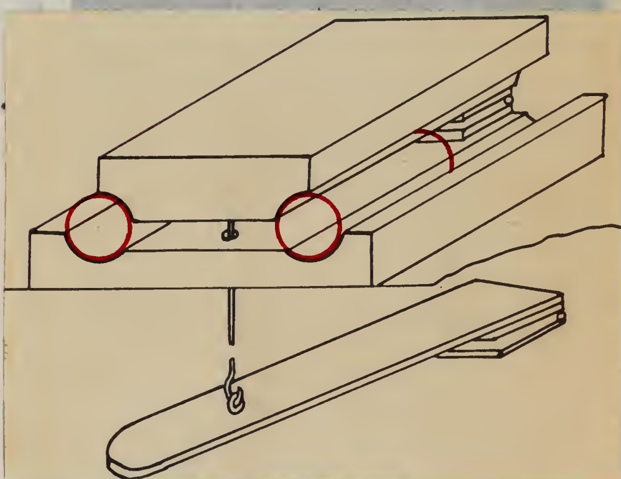

Fig. 2 Foot Operated Fixture For Holding Cylindrical Components

The top is spring loaded and the foot pedal may be detached to lay back out of the way.

The economy of resorting to the use of a fixture should be considered and will involve the savings to be realized by such use. In addition, the length of run, or number of pieces to be produced will influence this decision. Worthy of note here is the cost of holding fixtures for hand operations. Usually the degree of accuracy and rigidity required is such as to permit making the fixture cheaply and from inexpensive materials, as illustrated in Figure 3.

Fig. 3. Wooden Fixture For Holding Threaded Sections Of Double Faucet During Assembly of Apron and Valve Stems

Possibly a device already made can be adapted as by changing jaws and thus save the cost of making a new fixture. Also, looking ahead to future produc-

tion may suggest similar pieces which could use the device if preparations are made now for adapting it.

2. Purpose of holding.

This involves establishing what the workpiece would do if not held. Many times the purpose will combine two or more of the listed movements. The purpose will suggest to some extent the area where support must be furnished. For example, axial movement could be prevented by primary support at the end and steadying on the sides.

3. Best position to hold the piece.

This will be influenced by (a) providing the worker a clear view of the piece, especially the area(s) on which he is to work, (b) giving his hands free access and (c) considering the tools he is to use. The number and location of work areas will control the position in which piece must be held and possibly whether or not it can remain fixed.

If it can be used, the horizontal or flat position offers the advantage of the piece's own weight helping hold it in position. Also, if such tools as powered screwdrivers are to be used they may be suspended overhead in a readily accessible position. If the piece must be vertical, possibly

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If it can be used, the horizontal or flat position offers the advantage of the piece's own weight helping hold it in position. Also, if such tools as powered screwdrivers are to be used they may be suspended overhead in a readily accessible position. If the piece must be vertical, possibly

a device having a groove for the lower edge, guides for the sides, and a clamp on top may suffice and give rapid loading and unloading. (See Figure 4.)

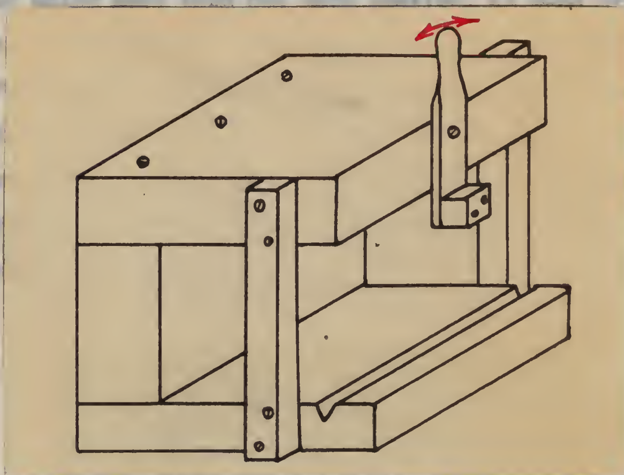

Fig. 4. Fixture For Holding Workpiece In Vertical Position

An intermediate position may be desirable to take advantage of increased operator efficiency at an optimum angle of inclination.[11] Intermediate positions may not require such clamping as indicated in Figure 4.

11. Halberstadt, H., Determination Of The Optimum Angle For A Work Area By Means Of Metabolic Measurement, Plus Instrumentation, Thesis, Purdue University, June, 1950

If the piece must be repositioned for several sub operations it complicates the design of the fixture. It may be wise to investigate the advisability of using more than one work station, at each of which are performed those sub operations which can be performed with the piece in each successive position. Should it be decided to reposition the piece at one work station for several sub operations such a device as is shown in Figure 5 or Figure 6 may be of use.

Fig. 5. Example Of An Indexing Fixture

Fixture shown in Figure 5 is used for holding meter frame for assembly of terminal brackets. Features of the fixture are: pins project into frame to position it and prevent rotation, notches on the edge of base, which with the detent on the left, stop and

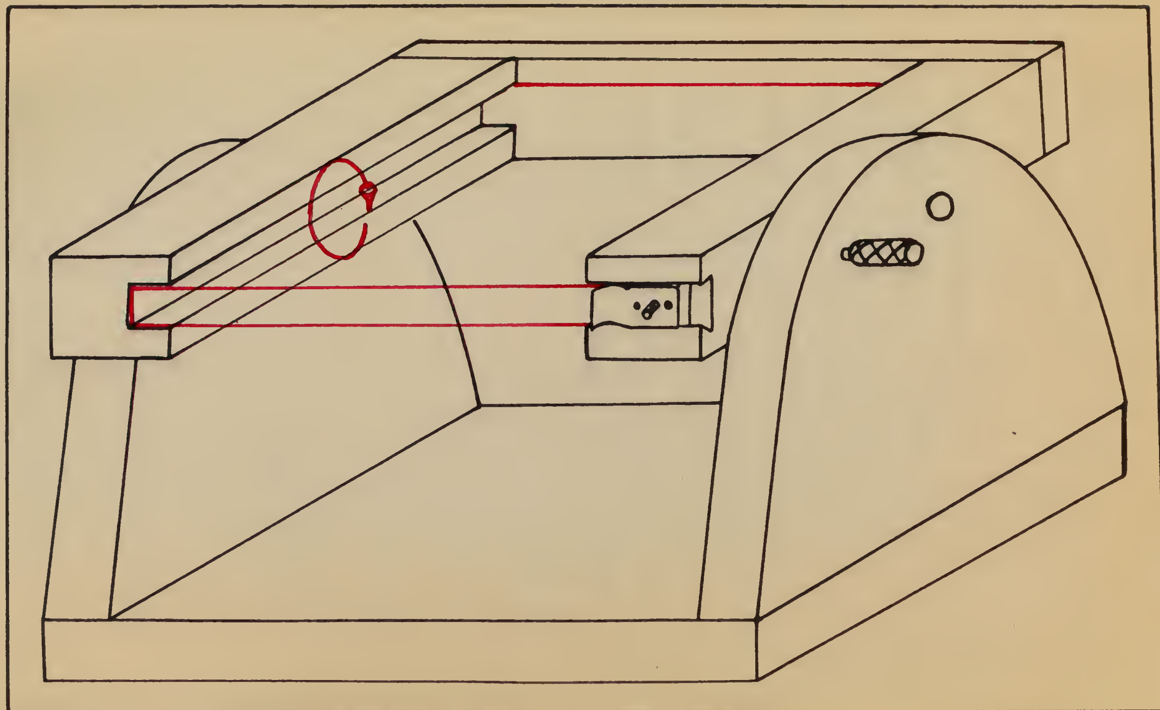

Fig. 6 Another Example Of An Indexing Fixture

hold piece in position for the presentation of successive work areas. A power driver is used to seat the bolts.

The fixture shown in Figure 6 could be used in holding a base plate to each side of which are to be assembled components, as by soldering. Retention of the plate in the desired positions is accomplished by means of a pin through the end support fitting into the rotable frame. The base plate is held in the grooved frame by means of a sliding clip which facilitates loading and unloading. Details of the clip and bracket end are shown in Figure 7.

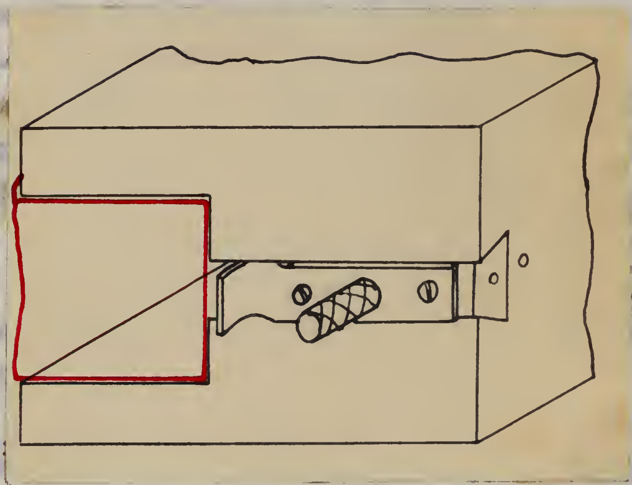

Fig. 7. Details Of Clip And Bracket End Of Fig. 6

The question of degree of fixation will arise under this consideration. For work which must be held rigidly in place, a foot operated vise would probably be best. (See Figure 1.) For other work more leeway is allowed and simplifies the fixture required.

4. Selection of piece or part of piece to HOLD.

It is often possible to take advantage of regular geometrical shapes by adaptation of conventional devices such as mating female wrench jaws.

If the shape is irregular it may be well to review the purpose of holding to see where on the workpiece it might be preferable to mechanically grasp it. This may permit taking advantage of regular cross sections for holding. Should this be impossible, the irregular cross section may be broken down into regular components, bridging the parts which it is deemed advisable not to support. (See Figure 8.)

At other times, if the irregularities are strong enough, they may be used to advantage to facilitate holding.

A broader consideration here is to weigh carefully the possible choices involved in determining which piece could most advantageously be held. The largest piece is not necessarily the best to hold.

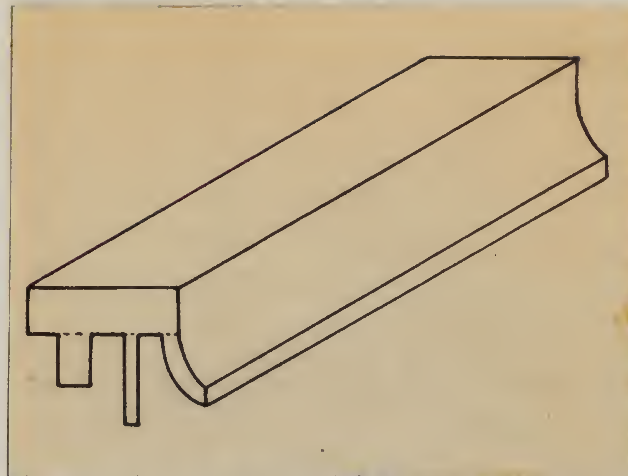

Fig. 8 Method Of Breaking Cross Section Into Regular Components

Fig. 9 Example Of Fixture For Two Handed Assembly

This consideration may lead to suggesting a revision of the operation as may be shown by the following example. An operation consisted of assembling to a brass cap a gasket and screw. Assembly in that order, holding the cap, was done at the rate of approximately 400/hour, or less. By holding the screw in a fixture and bimanually assembling to it in succession the gasket and cap, the rate was increased to as high as 750/hour. (See Figure 9 and Figure 10.)

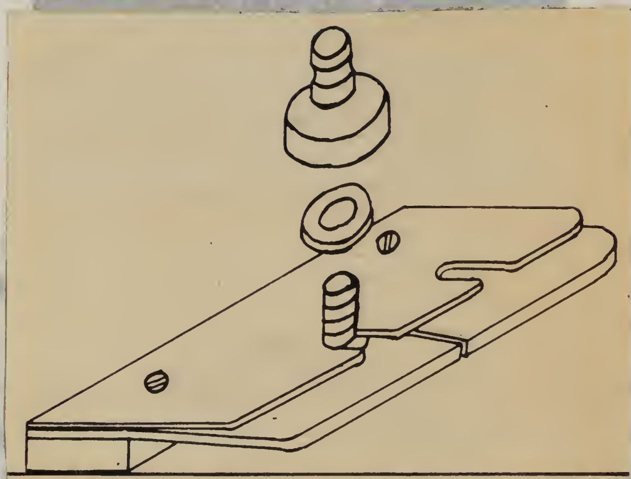

Fig. 10. Details Of Fixture Shown In Fig. 9

Where possible to do so, sliding of components to the assembly facilitates the operation since the efforts to grasp and release the piece are eliminated. Figure 11 shows a fixture for assembling a

metal washer and a snug fitting insulating sleeve to a bolt. The sleeves are first placed in the holes, the washers slid in on top and the bolts dropped through. A lever in front opens the device to allow the completed units to drop into a pan.

Fig. 11. Fixture Incorporating Sliding Of Components

Figure 12 shows a picture of a cardboard card which has been perforated to facilitate tearing into six parts. Holes previously stamped in the card are filled with buttons by pushing them through, while the edges of the holes are supported. Corner clips guide the card into the countersunk area it occupies while the buttons are positioned and assembled to it.

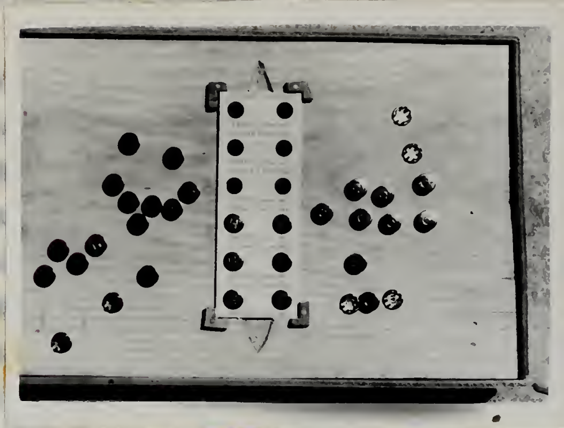

Fig. 12. Another Fixture Incorporating Sliding Of Components

5. Nature of the material in the workpiece.

The material from which the workpiece is made may be obtained from the specifications, prints or an examination of the piece itself. From this may be determined the nature of the material, which will in turn determine the amount of force that may be applied to the piece during holding and probably the kind of handling it must receive. As pointed out in the check list, combinations will exist.

6. Preservation of surface finish.

Consideration of the surface finish and what may be done to it may lead to suggesting a new sequence of operations. For example, an enameled piece of wood to be held for the assembly of another piece might better be painted after assembly. If not, then lining of the fixture contact surfaces with rubber or other soft material may be resorted to.

If the surface may be marred, less care need be taken in the facing of bearing surfaces. They may be serrated or knurled to facilitate gripping.

For finishes permitting slight marring, flat contact surfaces may be used to good advantage. Possibly a facing of some substance softer than the piece may be needed, as for example, copper facing for steel pieces.

When the surface finish must be preserved, it can usually be accomplished without much difficulty, as by the use of a rubber pad for supporting chrome plated surfaces.

Of interest is the fact that under most circumstances the variation of a given dimension from piece to piece will decrease from rough to semi-finished pieces and from there to finished pieces which in turn reduces the need for including allowance for such variation in the holding device.

7. Disposal of piece after completion of operation.

Preservation of finish and nature of material will influence the requirements for method of loading and unloading the device and also the disposal of the piece after the completion of the operation, as might the advisability of positioning the assembly completed at one work station for use at the next. This may be exemplified by several workers doing the same operation feeding their work to one worker for the performance of the next operation.

Figure 10 shows an example of drop disposal. Figure 8 shows an operation where one worker utilizes two fixtures to accomplish an assembly.

CONCLUSIONS

The proposed check list should prove to be a useful tool in effecting an improvement in work methods by aiding in the selection or designing of a device to eliminate HOLD. The principal benefits to be derived from the use of the check list result from the thinking provoked by a systematic analysis of the factors related to the occurrence of the therblig. Use of the proposed check list should result in such an approach to the problem.

The check list has not been validated by use, but should be reliable since it is based on accepted principles of fixture design and motion economy. By the use of the proposed check list these principles may be systematically applied to the therblig HOLD.

In order that any check list be most effective it must be conscientiously applied. The proposed check list, if so applied, should give the methods analyst a guide for dealing with the problem of eliminating HOLD.

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